# Mammoth Architecture

**An Honors Thesis (HONR 499)**

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May 2014

Expected Date of Graduation

May 2014

Abstract

A basic need of humans is protection from the elements. In order to provide this protection, structures have been built from the beginning of humanity. During the Paleolithic Era, mammoth bones were abundantly available and used to construct structures. As civilization has progressed, our understanding of building materials and practices has also developed. Using the knowledge architects have today, I revisit this building material to determine the most efficient way to construct huts out of mammoth bones.

Acknowledgements

I would like to thank Pete Davis for advising me on this odd adventure. Without him I would not have come up with the idea nor would I have had the knowledge of how to approach topic.

I would like to thank Rod Underwood for teaching me the math needed to understand the strength of building components. His class and book helped me arrive at my destination.

I would like to thank Milly Vanamala for being patient with me as I continually bragged about my excitement with this project.

I would like to thank my parents for sending me to college so that I have the opportunity to explore a topic such as this one.

Sustainability has become the new trend of architecture in the twenty-first century. Architects are being taught how to employ new technology as well as more effectively use common building technologies in order to create a more sustainable built environment for the world we inhabit. The most sustainable architectural practice is to reuse existing materials. Designers are becoming known for their ability to use creativity to bring back to life objects that no longer serve their original purpose. Abandoned buildings are being revitalized, worn tires are being salvaged for reused rubber, and wooden pallets are being used as structural members. As inventive as designers think they are today, they may be simply copying the actions of humans thousands of years before them.

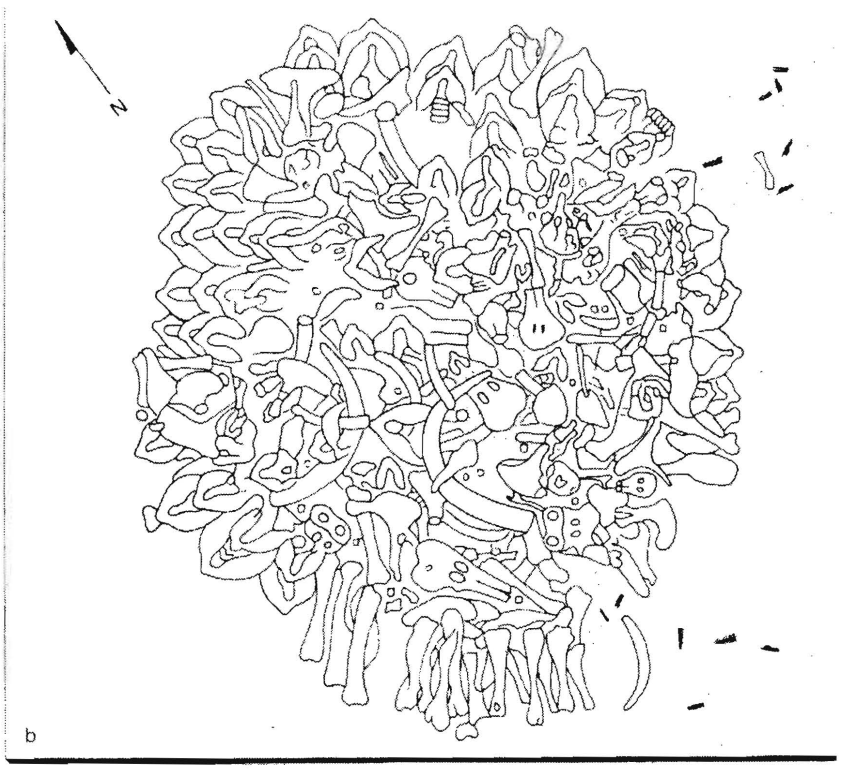
From the beginning of humanity, protective shelters have been an essential part of survival for the human race. Before the technology we have access to in today's world to create building materials, humans have been challenged with creating these shelters from objects they can find around them. The creativity architects now brag about was the difference between life and death thousands of years ago. One of the most abundant and practical resources available to humans at the time were bones from animals. Bones are simply structural elements for the bodies that contain them. They are the same for people as steel, wood, and concrete are to buildings today so it makes sense for people during the Paleolithic era to use the abundant resource for their shelters.

Imagine coexisting with mammoths standing up to fifteen feet tall and weighing up to three tons with seventeen feet long tusks. Intimidating while alive, but so beneficial when dead. Not just any animal will provide a skeleton capable of being used by humans for structures, but the massiveness of a mammoth provides this need. The availability of these bones is also beneficial for humans. In the book "After the Ice" by Steven Mithen, a single site is described to

explain the availability of mammoth bones. "Vereshchagin used a water cannon to wash away the enclosing sediments, exposing the remains of perhaps two hundred mammoths along with those from bison, horse and reindeer. While doing so he found four flint artefacts within a scatter of bones a short distance from the main deposit" (Mithen, 2004). This find shows the availability of mammoth bones at this time period as well as proves humans chose to settle near this resource. During the Paleolithic era, humans were nomads. They travelled from place to place in search of food. Since we know this, we can also know that shelter was a temporary need that had to be able to be constructed quickly and easily with materials readily available.

Many archeology sites have been found containing remains of huts constructed out of mammoth bones. "Archeologists, especially in the Ukraine, and as far west as southern Poland, have uncovered many late Pleistocene sites containing huge quantities of mammoth bones" (Davis, 1987). The author goes on to state "most of these mammoth bones occurred in patterned arrangements suggesting ruins-they seem to have served as constructional material. This idea is supported by the strongly disproportionate representation of certain parts of the skeleton. Most of these bones were probably scavenged from the skeletons of animals that had died naturally." Ruins such as these consisted of more than one mammoth, often times consisting of over one-hundred different mammoth skeletons. "Ivan Pidoplinchko excavated some of the most spectacular bone ruins so far found in the Ukraine. At Mezhirich, in the Cherkassy Region for example, he found a ruin consisting of 385 mammoth bones covering a circular area 4-5 m across." "The base of the structure consisted of a circle of some 25 mammoth skulls, each arranged so that its frontal bones faced inwards. Other elements which made up the foundation were 20 mammoth pelves and 10 long bones embedded vertically in the ground. On top of these and the skulls were 12 more skulls, 30 scapulae, 20 long bones, 15 pelves and segments of seven

berebral columns. Still higher and presumably for holding down skins over the wooden framework there were 35 tusks. Ninety-five mammoth mandibles, piled up in columns around parts of the foundation, may have served as a peripheral retaining wall" (Davis, 1987). Images of the excavation site and a reconstruction of what the ruins might have looked like are below.

Another example of a mammoth bone settlement is located in the Udai Valley near Lubny in the Ukraine. This settlement is known as Gontsy and it includes at least six separate dwellings made of mammoth bones. The site is believed to have been occupied twice during the Late Upper Paleolithic period. "The largest of the huts is more than 6 m (20 ft) in diameter, with a surface area of some 40 square meters (430 square feet). About 2/3 of the structure has been excavated to date, and so far 125 mammoth tusks, 60 scapulae, 20 skulls, 10 pelves, 12 long bones and five mandibles have been recovered from the area. The most completely excavated of the dwellings includes a circular foundation of 28 mammoth skulls, in a diameter of just under 6 m (20ft)… Several refuse pits surround the hut, filled with bones and other artifacts. Animals represented in the pits include reindeer bones (mainly feet), mammoth teeth and burned bone fragments, which suggest these represent the final processing of the animal for consumption. Further away from the hut is a series of ash accumulations, all with burnt bones and flint artifacts. A wide scatter of reindeer bone and antler, some partially articulated rabbit bones and

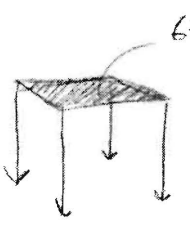
larger mammoth fragments appear to have resulted from butchering" (Hirst, 2014). The information regarding the bone pit is included in this paper to demonstrate the relationship between humans and animals in these settlements. Mammoths are as important to the people of these settlements as deer and rabbits, a common source of food. Mammoth bones were part of everyday life, and essentially part of the survival of these humans. Just as survival would be more difficult without easy game such as rabbits and deer, survival would be just as difficult without mammoth bones to use for structures.

Before we investigate the capabilities of mammoth bones used as architecture elements, we must first begin by understanding how the structures were constructed during the Paleolithic Era. Most research includes a wood structure existing on the interior of these huts to provide extra support to help the bones stay in place. Wood is easier to work with and can be found in a variety of thicknesses and lengths. This material made it easy to form the dome shape to allow the primary bone structure to be constructed. The most predominant bones noticed when seeing the huts are the large tusks creating the opening. Using the two tusks mirrors creates an archway that is similar to that found in architecture still today. This arch creates an element perfect for supporting weight above it and transferring it to the ground safely. It also creates a large feature to mark the entry welcoming people in. The base of the hut is composed of pelves interlocking. Stacking these bones creates a strong base that can carry all of the other bones. The form of the pelves allow for a sturdy connection which is needed to ensure the entire structure does not collapse. From here, it simply becomes a stacking and balancing act. Each reconstruction produced from archeologists seems to imply a different order. After studying all of them, it appears these huts were constructed with whatever worked. Protection from the outside was the main goal, so any bone that fit closely together with the one next to it worked fine. These huts

were built as quickly as possible with the bones available, so no two huts are likely to be identical. Once the structure was complete, they were often covered with animal skins to protect from the wind.

Archeologists are still finding these huts and determining how they were constructed. After understanding the purpose of these huts and how people during the Paleolithic Era used the bones, we can suggest a more effective way to use the mammoth skeletons. Steel, wood, and concrete are the most popular building materials in today's world. As time passes, we better understand the properties of these materials and the most efficient ways to use them. Understanding the physical properties of mammoth bones, mainly the structural capacity or how much load it can carry, allows us to determine what the people during the Paleolithic Era could have done with the mammoth bones to create efficient huts. Before exploring these ideas, it would be helpful to compare the physical properties of mammoth bones to that of wood, steel, and concrete to have a better understanding of the material being used during the time of mammoths.

The easiest to calculate bones are in the legs of the mammoths. Since a mammoth weighs three tons, or six thousand pounds, it means that fifteen hundred pounds are equally dispersed through all four legs. Also a safe number to use for the height of these legs is six feet tall. To calculate comparable structural capacities, I need to design a six feet tall column that can support fifteen hundred pounds of force. After doing this for wood, concrete, and steel, I will be able to better understand how effective mammoth bones are for building huts.




1500 #/leg

Section area of mammoth leg =

$\frac{1500\#}{in^2}$ = psi

$P = F \cdot A$

$1500\# = F_{psi} \cdot in^2$

Wood

Load: 1500 #

Height: 3'

D. Fir Larch

$F_{cII} = 1500 psi\ (1.1) = 1650$

$E_{min} = 620{,}000 psi$

$P = F \cdot A$

$P = 1500 psi (1.5)(\ \ )(1.5 \times 1.5)$

$$\frac{1 + \frac{F_{cE}/F_{cII}}{2c} - \sqrt{\left(\frac{1 + \frac{F_{cE}}{F_{cII}}}{2c}\right)^2 - \frac{F_{cE}}{c}}}{0.8} = \frac{1 + \frac{124.4}{1650}}{2(.8)} - \sqrt{\left(\frac{1 + \frac{124.4}{1650}}{2(.8)}\right)^2 - \frac{\frac{124.4}{1650}}{.8}}$$

$= 0.67 - \sqrt{0.67^2 - 0.09}$

$= 0.07$

$F_{cE} = \frac{.822(620{,}000)}{\left(\frac{8' \times 12''/'}{1.5''}\right)^2} = 124.4 psi$

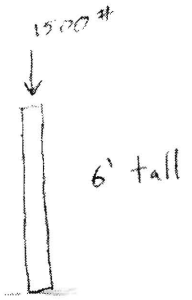
$P = 1500 psi\ (1.5)(.07)(1.5 \times 7.25)$

$P = 1{,}712.8\#$

2 x 8

The equation for determining the size of a wood column includes the force applied to the column, the strength of the wood used, a size factor, a column stability factor, and the area of the column. The force being applied to the column is the fifteen hundred pounds explained earlier. A size factor relates to the proportions of the column, whether it is thick, thin, or square. Column stability factor ensures the column height to width ratio will be appropriate so that it won't buckle in the middle. And finally the area of the column is the amount of wood that exists in the column provided structural capacity. We know all of the factors other than how large the column is going to be so I filled in the numbers and arrived at a solution of four two-by-eight wood columns would support the weight of a wooly mammoth. Two two-by-four wood studs are the most common wood members used in construction. Mammoth bones are almost twice as strong as these wood studs.

# Concrete Column (Square) (tied)




$$P = \phi K_e R A_g [.85 f_c' (1-\rho_g) + F_y \rho_g]$$

$1500\# \times 1.7 = 2550\#$

$h = 6'$

$f_c' = 3{,}000 psi$

$F_y = 50{,}000 psi$

$R = 1.07 - \frac{.0084}{r}$

$r = .3 \cdot \text{min dim.}$

$2{,}550\# = (0.65)(.80)(1)\, A_g [.85(3000 psi)(1-.03) + 50{,}000 psi(.03)]$

$4{,}903.8\# = A_g [2550 psi - 76.5 psi + 1500 psi]$

$4{,}903.8\# = A_g (3{,}973.5 psi)$

$A_g = 1.23 in^2 \quad \sqrt{1.23} = 1.1 \rightarrow 2'' \text{ square column}$

$R = 1.07 - \frac{.0084(6' \times 12'')}{.3(2'')}$

$R = 0.11 \leq 1.0 \checkmark$

$2{,}550\# = (.65)(.80)(.11)(4 in^2)[.85(3{,}000 psi)(1-\rho_g) + 50{,}000 psi(\rho_g)]$

$11{,}145.1\# = 2550(1-\rho_g) + 50{,}000(\rho_g)$

$11{,}145.1\# = 2550 psi - 2550\rho_g + 50{,}000\rho_g$

$8{,}595.1\# = 47{,}450\rho_g$

$\rho_g = 0.18$

$\rho_g = \frac{A_s}{A_g} \rightarrow A_s = \rho_g \cdot A_g$

$A_s = .18(2'' \times 2'') = 0.72 in^2$

2" x 2" column with .72 $in^2$ steel

To calculate an equal column made out of reinforced concrete a different equation is needed. This equation has variables that represent the load applied to the column, the strength of the concrete, the strength of the steel reinforcement, safety factors to ensure it doesn't fail, and the amount of steel needed for reinforcement. This equation is a bit more in depth because of the extra variables and the use of two materials. Once solved, I found that a two inch by two inch square column with seventy-nine one-hundredths square inches will support the weight of a mammoth. This is a tiny column that would never be constructed in real life due to the impracticality of it. Compared to concrete, mammoth bones are not a very strong building material.

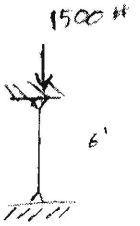
# STEEL COLUMN

$F_{cr} = \frac{P}{A}$

$\frac{KL}{r}$

$P = 1500\#$

$A$ - area




$K = 1$

$KL = 72"$

$\frac{KL}{r} = 80$ → estimate

$F_y = 50\ ksi \Rightarrow F_{cr} = 28.2\ ksi$

$r = \frac{KL}{80}$

$r = \frac{72"}{80}$

$r = 0.9"$

$F_{cr} = \frac{P}{A}$

$A = \frac{P}{F_{cr}} = \frac{1.5^K}{28.2} = 0.05\ in^2$

$A = 0.05\ in^2$

$r = 0.9"$ ⟹

W4 x 13 (Smallest I-beam I)

↳ $r = 1.00\ in$

$A = 3.83\ in^2$

$\frac{KL}{r} = \frac{1.0(72")}{1.00"} = 72$

$\frac{KL}{r} = 72 \rightarrow 30.8\ ksi$

$F_{cr} = \frac{P}{A} \Rightarrow P_{cr} = A F_{cr}$

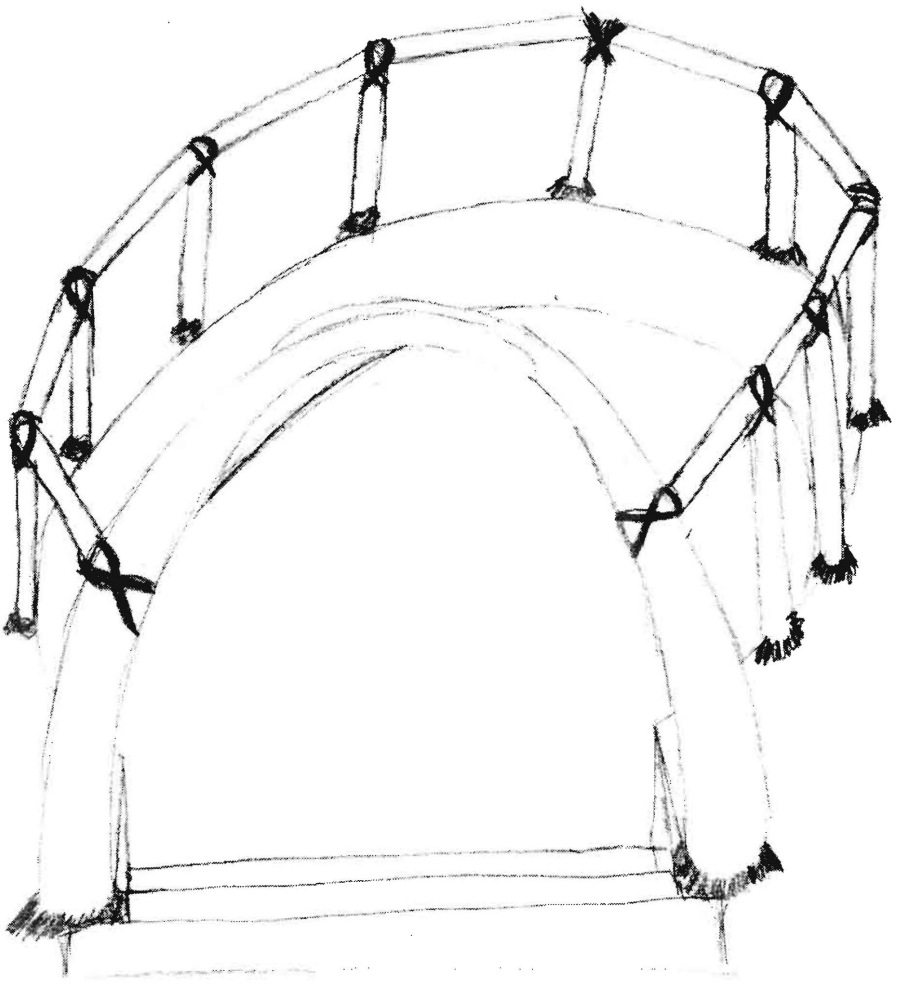
$= 3.83\ in^2 (30.8\ ksi)$

$= 117.9^K > 1.5^K$

**W4x13**

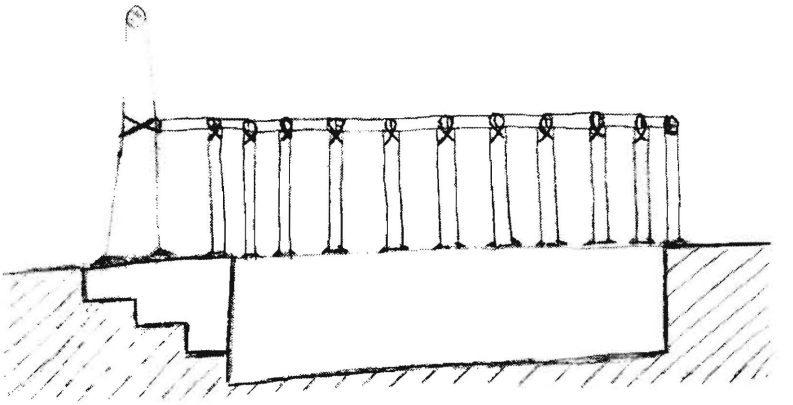
The last solution I searched for was a steel column. This equation included variables that represent the load applied to the column, the height of the column, the connection types at each end of the column, the strength of the steel, and the amount of steel needed. Since steel is stronger that concrete I was able to anticipate the solution to this equation. Only five-hundredths square inches of steel is needed to support a mammoth. The smallest steel column that is constructed is a W4x13 which has an area of three and eighty-three hundredths square inches. This column is over seventy-six times stronger than necessary to support a mammoth. Therefore, even more so than concrete, mammoth bones do not compare to steel as a building material.

The only building material comparable to mammoth bones is wood. A two-by-eight wood stud is a common member that can be purchased at any hardware store that sells wood. Since mammoth bones are equivalent to a two-by-eight piece of lumber, which is twice as strong as the typical two-by-fours, it means that theoretically a house could be constructed out of mammoth bones rather than wood and be twice as strong. That doesn't work today since wood is more available than mammoth bones, yet that wasn't true during the Paleolithic Era. Using the plethora of bones available, huts could have been constructed similarly to the way they are built now with bones rather than wood.



Above is an image of how I believe the huts should have been constructed. The problem with mammoth bones is they aren't as long as wood boards. This means the bones have to be spaced closer together, but since there is not a shortage of bones I feel it is possible. The first change I made was the hut is dug out four feet into the ground. This allows the bones to be used most efficiently as structure as well as creates more space inside of the hut. People during the Paleolithic Era were correct by using the tusks to create the doorway. The strength and shape of these bones create a perfect archway to support the rest of the hut. Rather than using a stick frame, I used the three foot long shin bones of the mammoth for the structural skeleton. This creates a stronger structure that can be used for a longer period of time. These shin bones are

placed vertically in the dirt and are spaced three feet apart. These bones need to be resting on either a stone or a flat bone to keep them from sinking into the ground. The three foot spacing allows other shin bones to be placed horizontally between the vertical bones. Each connection needs to be tied together using leather or any other material that can be wrapped around the bones to hold them together. These bones provide the same structure that sticks previously provided, but they are stronger and will last longer. If huts were constructed this way, they may have been able to be reused as herds were followed across the lands.



Section of proposed hut

If humans during the Paleolithic Era had the knowledge we do now, their huts could have been constructed more efficiently improving their lives. If huts were constructed the way I have specified, they could have been more permanent saving time from constructing new huts. That is all that a better hut can really provide, yet it is still an improvement. The building industry has come a long way since the Paleolithic Era, but that progress has come from learning from those who came before us. We can learn a lesson from humans during this time period by emulating their effort to use what is around them to construct buildings out of. Their approach with the knowledge we now possess could combine to create a revolutionary change in the way we see architecture.

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